

An aerial photograph showing the aftermath of a bridge collapse. The bridge deck has fallen into a deep trench, and several cars are overturned on the remaining sections of the bridge. Debris is scattered across the road surface. In the background, there are buildings and utility poles. The scene is a stark illustration of the damage caused by the 2010 Chile Earthquake.

# Damage of Transportation Facility due to 2010 Chile Earthquake

April 5, 2010

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Hoshikuma, J. and Kosa, K.

Bridge Team Dispatched by  
Japan Society of Civil Engineers

AP

# 46 bridges located at 31 sites were investigated

## Suburbs of Concepcion

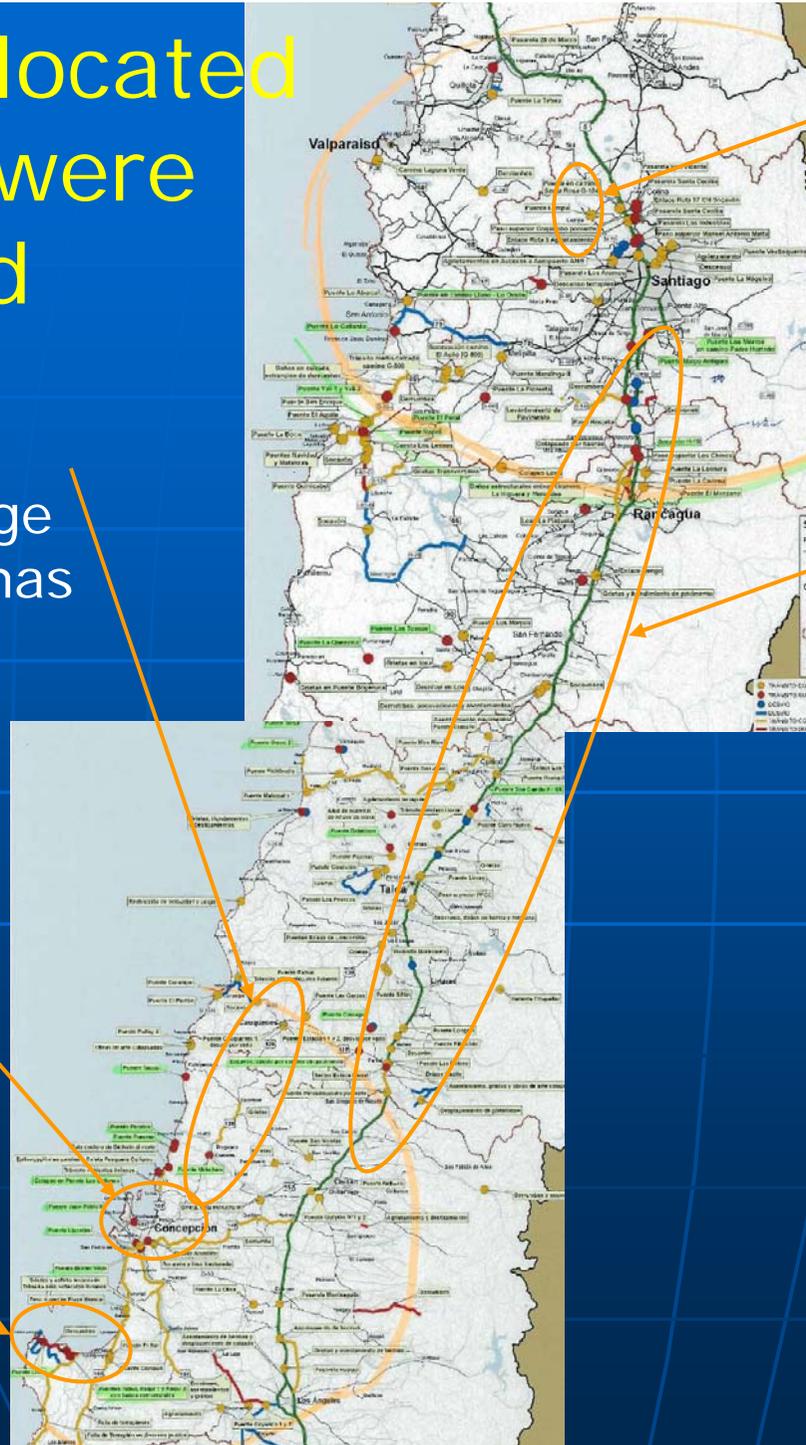
- 27. App. bridge
- 28. Las Ballenas
- 29. Lirquen
- 30. Itata

## Concepcion

- 19. Juan Pablo II
- 20. Llacolen
- 21. Bio Bio
- 22. La Mochita
- 23. Laraquete

## Arauco

- 24. Raqui I
- 25. Raqui II
- 26. Tubul



## Santiago

- 1. Miraflores
- 2. Lo Echeveres
- 3. Americo Vespucio
- 4. San Martin
- 5. Emanuel Antonio

## Route 5

- 6. Maipo
- 7. Hospital
- 8. Pedestrian bridge
- 9. Augustura
- 10. Graneros
- 11. Les Mercedes
- 12. Rio Claro
- 13. Rio Maule
- 14. Longavi
- 15. Copihue
- 16. Parval
- 17. Perquillauquen
- 18. ? (Gerbar hinge)

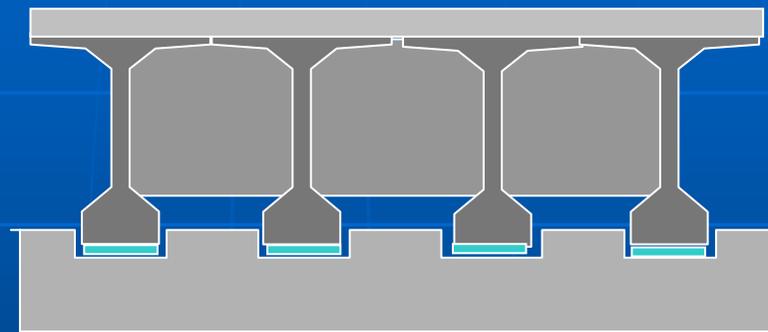
# Types of Damage

- Damage resulted from insufficient integrity of pre-cast concrete girder bridges due to absence of diaphragms
- Lack of constraint to rotation of deck in skewed bridges
- Damage of piers and foundations in bridges built in the early days
- ....

# Why was damage extensive in bridges built in recent years?

## Pre Mid-1990s Typical Chile Bridges

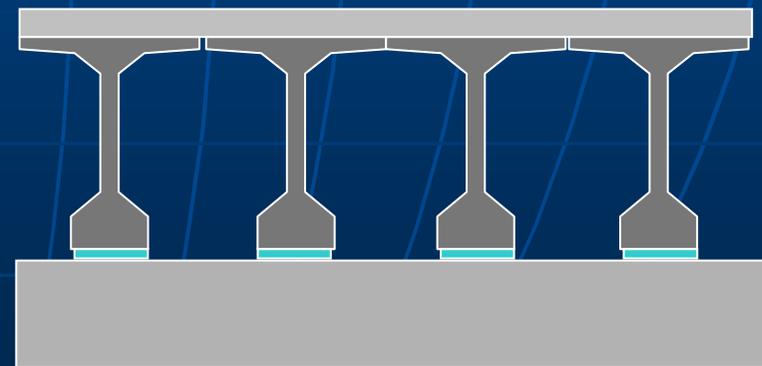
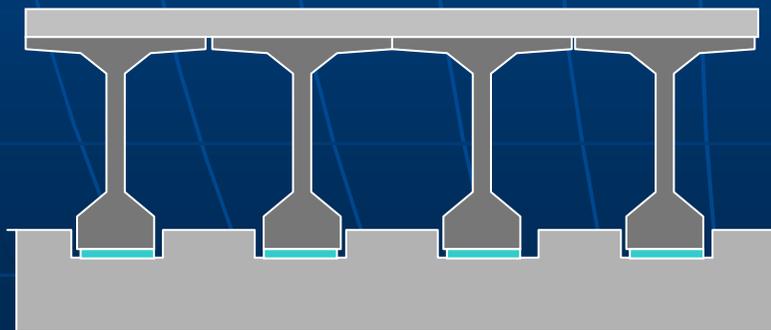
Pre-tension  
PC girders



Diaphragm

Cap beam

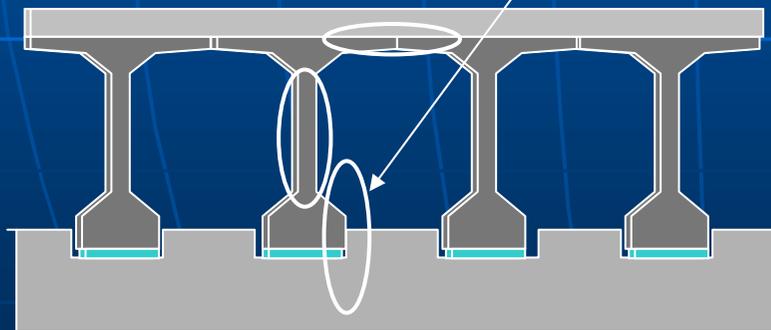
## After the Mid 1990s influenced by Spanish practice



# What happened in the bridges with insufficient integrity due to absence of diaphragm?

Contact of a PC girder to stopper results in failure of lower flange, shear failure of web plate, rupture of deck slabs and connection between deck slab and upper flange

Seismic force in the TR direction



Example of damage  
due to lack of  
diaphragms

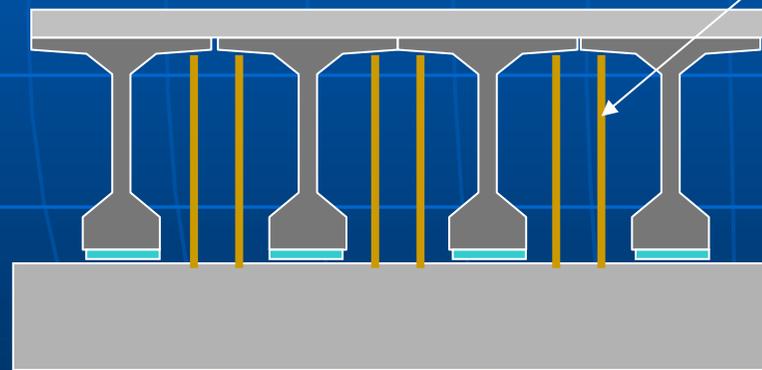
Llacolén Bridge  
Concepcion



From Web



What happened if side stoppers on the top of pier cap were removed in addition to removal of diaphragms?

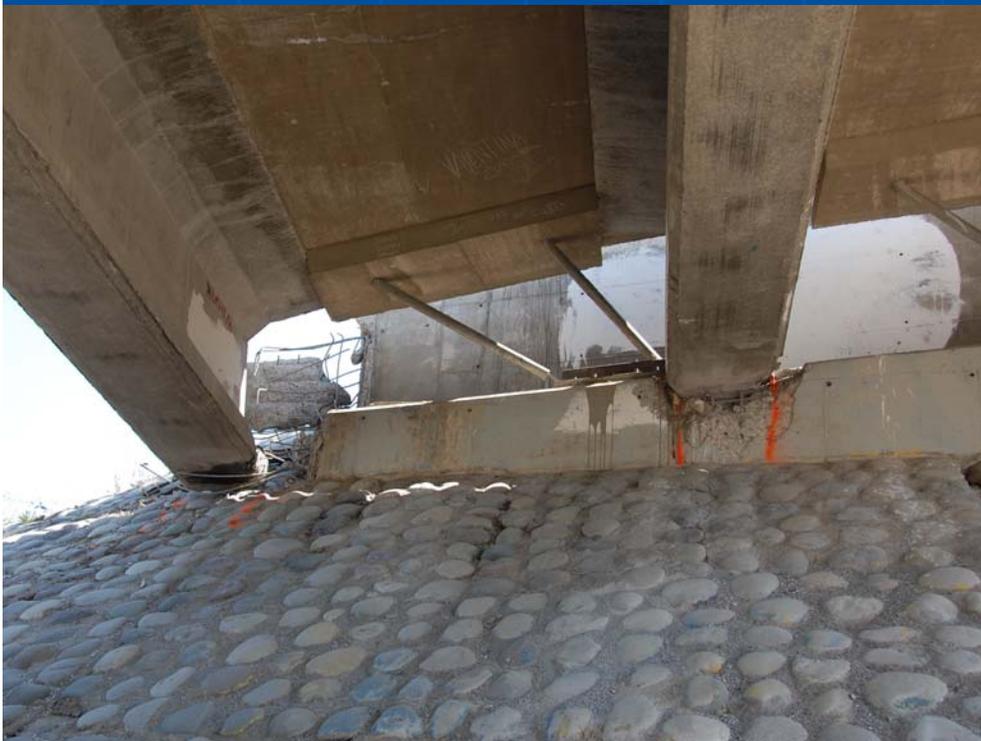


Vertical restrainers?

- Resist Uplift?
- Insufficient to constrain offset of a bridge in the transverse direction

Example of damage  
due to lack of side  
stoppers and  
diaphragms

Las Mercedes Bridge  
Route 5



Bridges based on recent practice suffered more damage than bridges based on pre mid-1990s practice

Perquillauquen Bridge  
Route 5

Very lucky!  
About to collapse



# Lack of constraint to rotation of skewed bridges

Skewed bridges tend to rotation under seismic excitation



Watanabe, G. and  
Kawashima, K., Paper No.  
789, 13<sup>th</sup> WCEE, 2004

Skewed bridges which lacked diaphragms and effective side stoppers suffered extensive damage

Lo Echeveres Bridge, Santiago



From Web

Miraflores Bridge



From Web

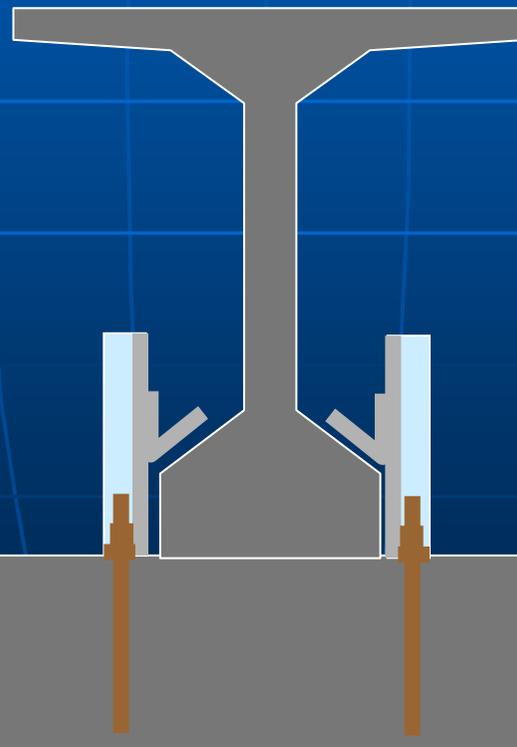
# No mechanism to prevent TR and LG offset of bridges

Miraflores Bridge, Santiago



# Stoppers for uplift?

- They were set not for preventing TR offset of bridges but for uplift prevention
- They were too weak



Skewed PC girder bridges recently built without diaphragms and effective side stoppers suffered extensive damage

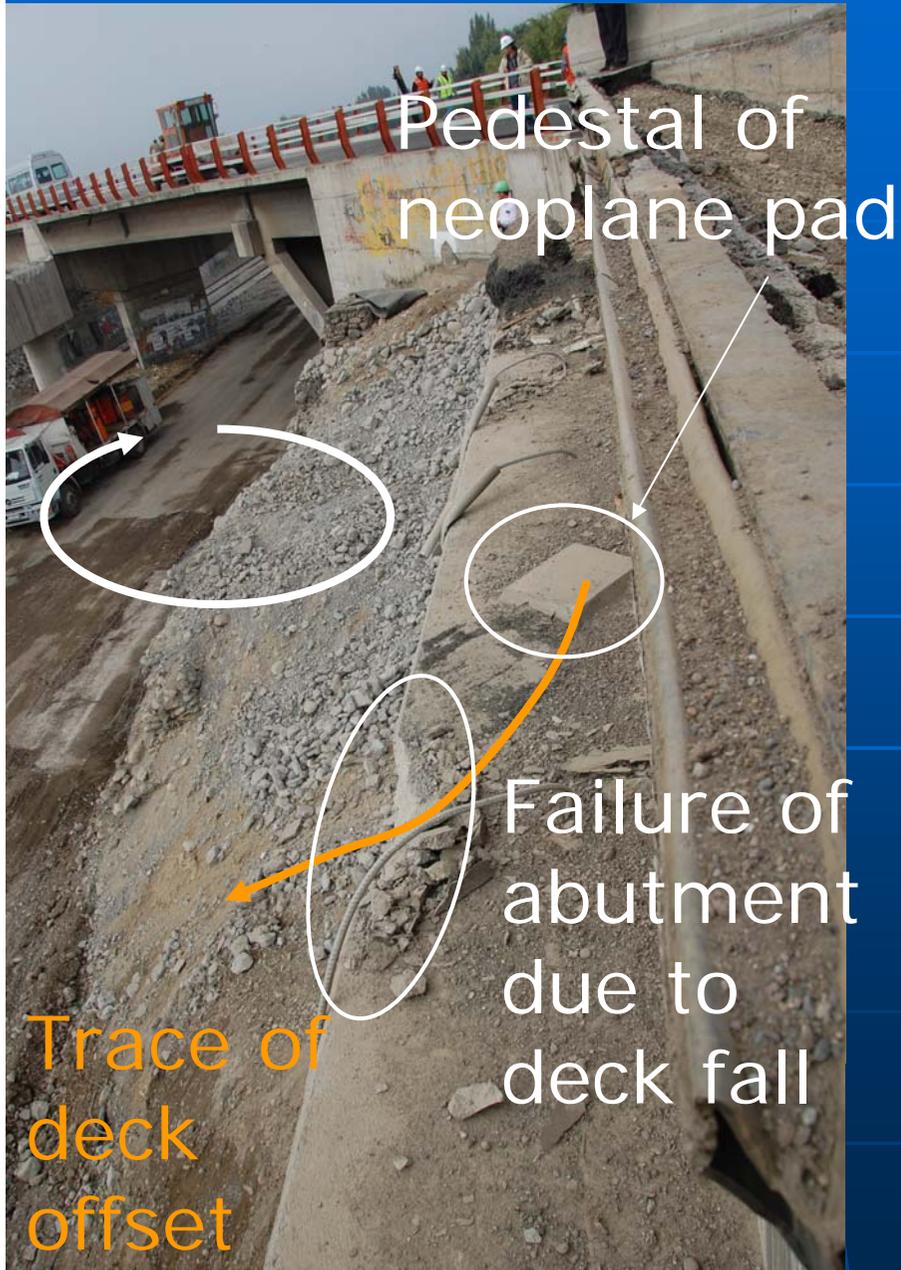
Hospital Bridge  
Route 5

Recent practice



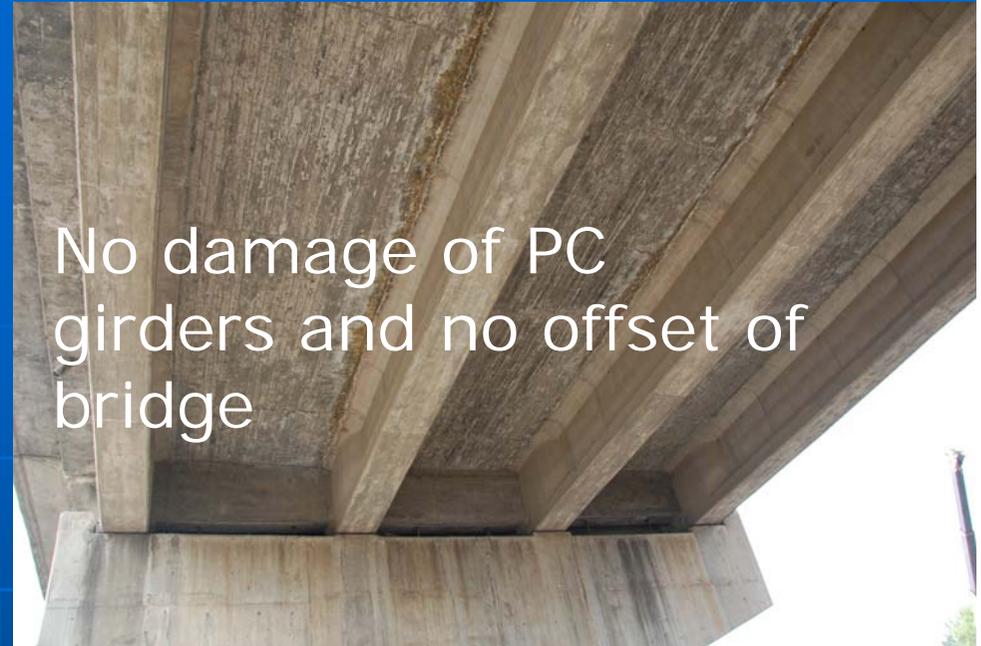
Pre mid-1990s Chile design practice

# Collapse due to rotation of a skew bridge

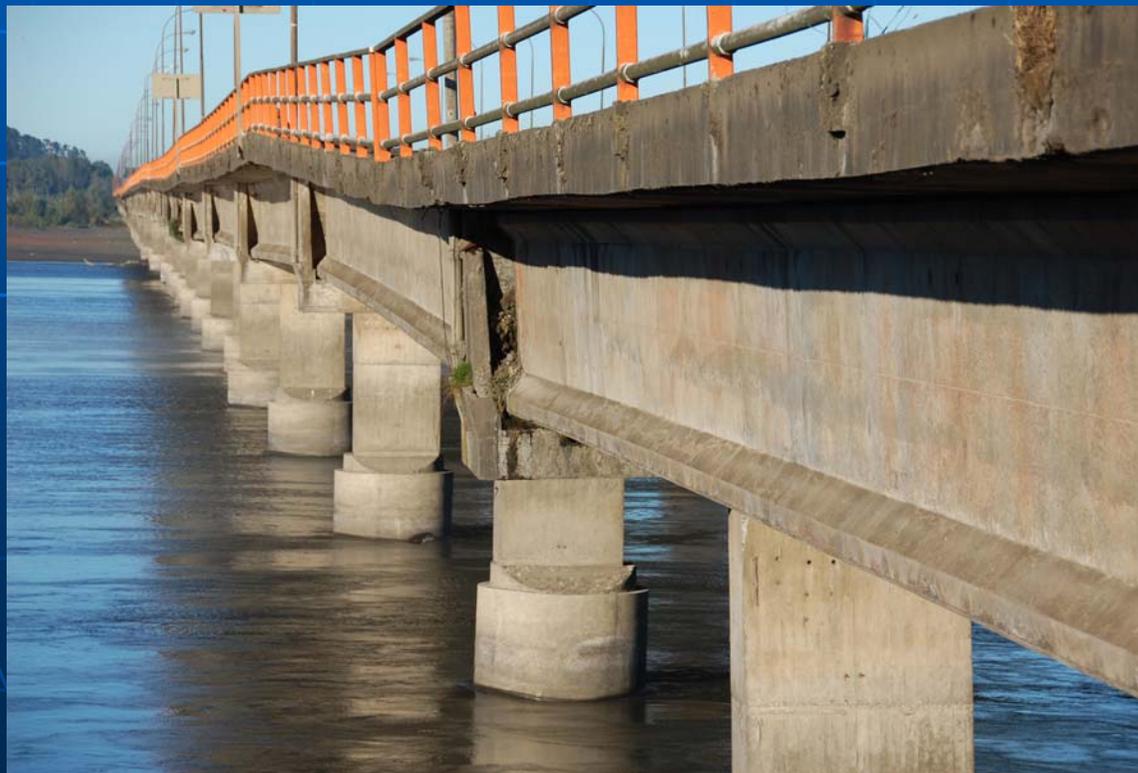


Older bridge based  
on Pre Mid-1990s  
Chile Design Practice  
performed well

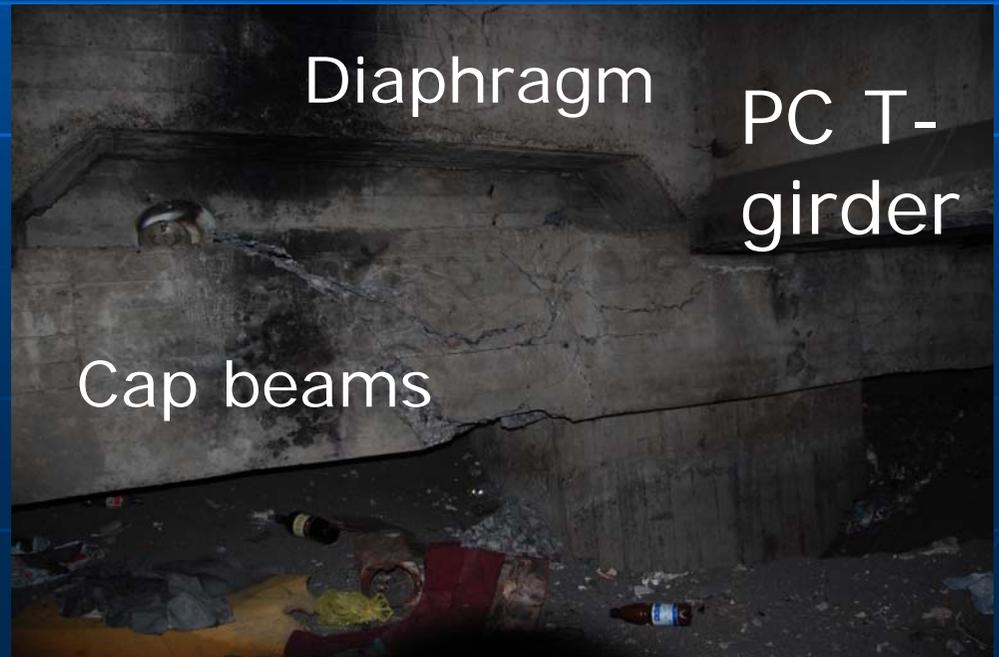
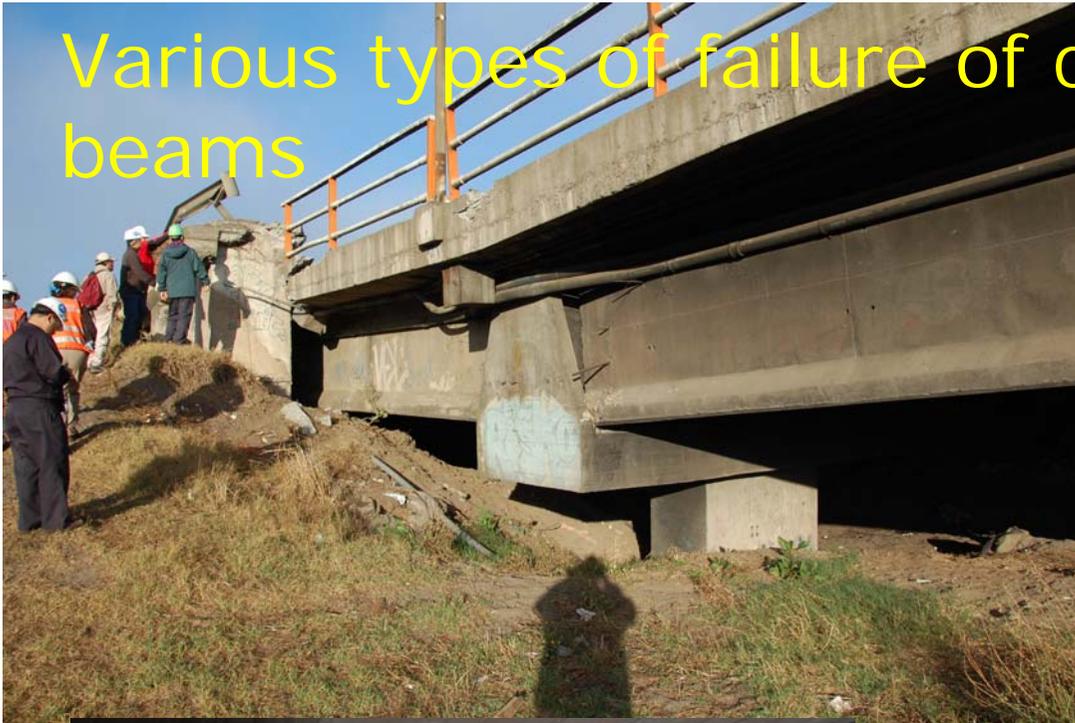
Abutments and piers  
were built perpendicular  
to bridge axis (straight  
bridge)



# Juan Pablo II Bridge



# Various types of failure of columns and lateral beams



# Thank you for long contribution!

## Rio Claro Bridge

A 140 years old unreinforced masonry bridge built in 1870







Claro Bridge  
survived heavy  
duty for long time

Brittle masonry  
easy to remove  
clay soil

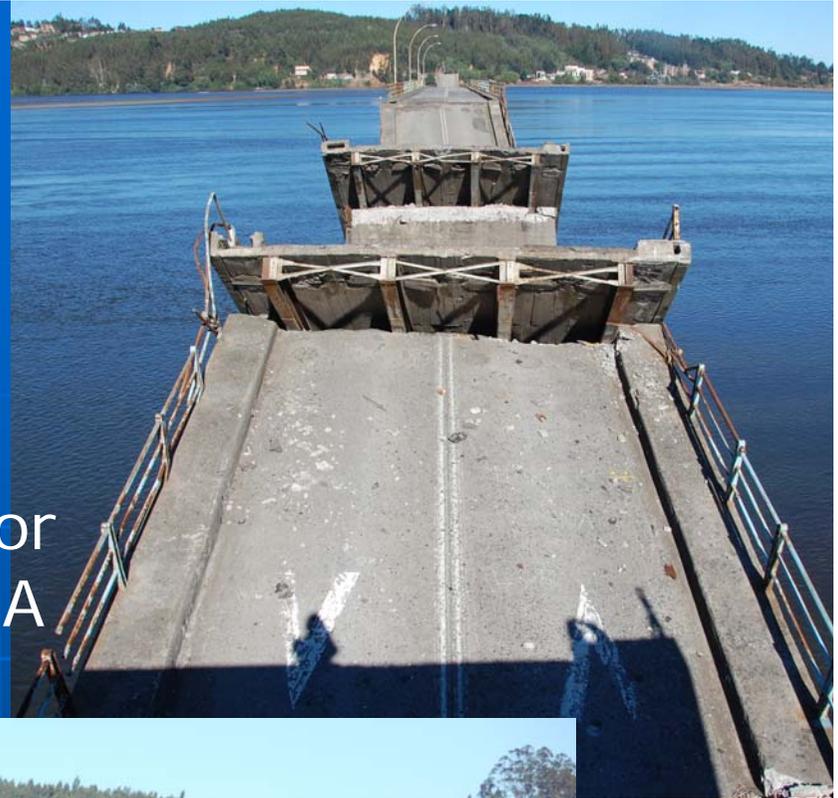


- Arch crown was only 3m thick
- It must be very tough to survive heavy traffic

Thank you for long  
contribution!

## Bio Bio Bridge

- Built in 1930s
- Recognized to be insufficient for traffic since 1990s based on JICA evaluation



# Tubul Bridge Arauco

Insufficient  
performance  
of foundations



# Rupture of Elastomeric Bearing

Las Ballenas Bridge

Local Road, Suburbs of  
Consepcion



A 15 cm tall  
60cm by 60cm  
elastomeric  
bearing ruptures  
due to shear at  
shear strain of  
about 70%

A new bridge constructed based on the existing Chile design survived with only very minor damage

- Side stoppers
- Diaphragms



## SUMMARY

- Lack of integrity of a bridge due to absence of diaphragms and effective stopper mechanism in the transverse offset resulted in extensive damage in bridges built after the mid 1990s.
- The above deficiency was particularly intensified in skewed bridges resulted from rotation of a whole bridge.
- In contrast to the bridges built after the mid 1990s with insufficient insight to the seismic effects, the bridges which were built based on the original Chile practice did not suffer extensive damage.

## SUMMARY (continued)

- Damage of columns/piers and foundations was not extensive except those in bridges built in the early days. However it is suggested to clarify their strength and deformation capacity if Chile practice moves toward higher connection between decks and substructures for limiting relative displacement.

# ACKNOWLEDGEMENTS

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